Lean Engineering

Integrating 6-Sigma, VM, and Lean into DFSS

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Freudenberg – NOK

Value Creation Workshop
IMEC & JMC
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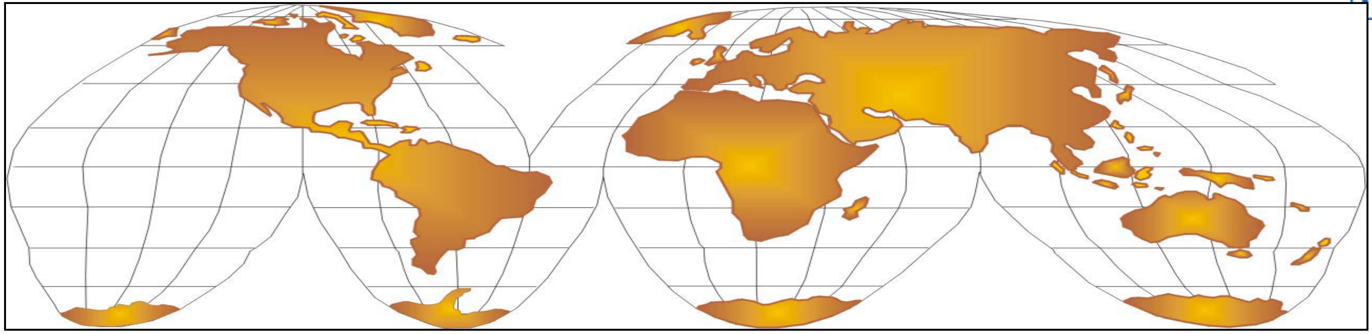
Growtth Six Sigma

The Freudenberg & NOK Global Partnership Serving Customers Worldwide

WORLDWIDE

- Global R & D technology exchange
- Globally integrated supply of products from factories in 27 countries
- One-piece-flow lean manufacturing
- “Zero Warranty” focus
- Over 30,000 employees serving our customers
- Total global sales over $7.5 billion
- Total automotive sales of approximately $4 billion

Better Global Capabilities



57 Automotive Operations

25 in North and South America

21 in Europe

11 in the Pacific Rim

$4.0 Billion Automotive Sales

$1.5 billion in Europe

$1.5 billion in the Pacific Rim

$1.0 billion in the Americas

Freudenberg-NOK

Annual Sales: Approximately $1.0 billion
Employees: Approximately 6000
Headquarters: Plymouth, Michigan

- Established July 1, 1989
- General Partnership between Freudenberg of Germany and NOK of Japan
- Integrates Japanese, German and American technology
- 25 Locations in the Americas

Designs and Manufacturers:

- Seals and gaskets
- Custom molded rubber products
- PTFE and plastic components
- Anti noise, vibration and harshness products
- Brake hoses
- Rebuild kits

Manufacturing Locations in the Americas

- 6,000 Employees
- Produce 2 Billion Seals & Molded Parts Annually
- Over 2.0 Million Square Feet of Factory Floor Space

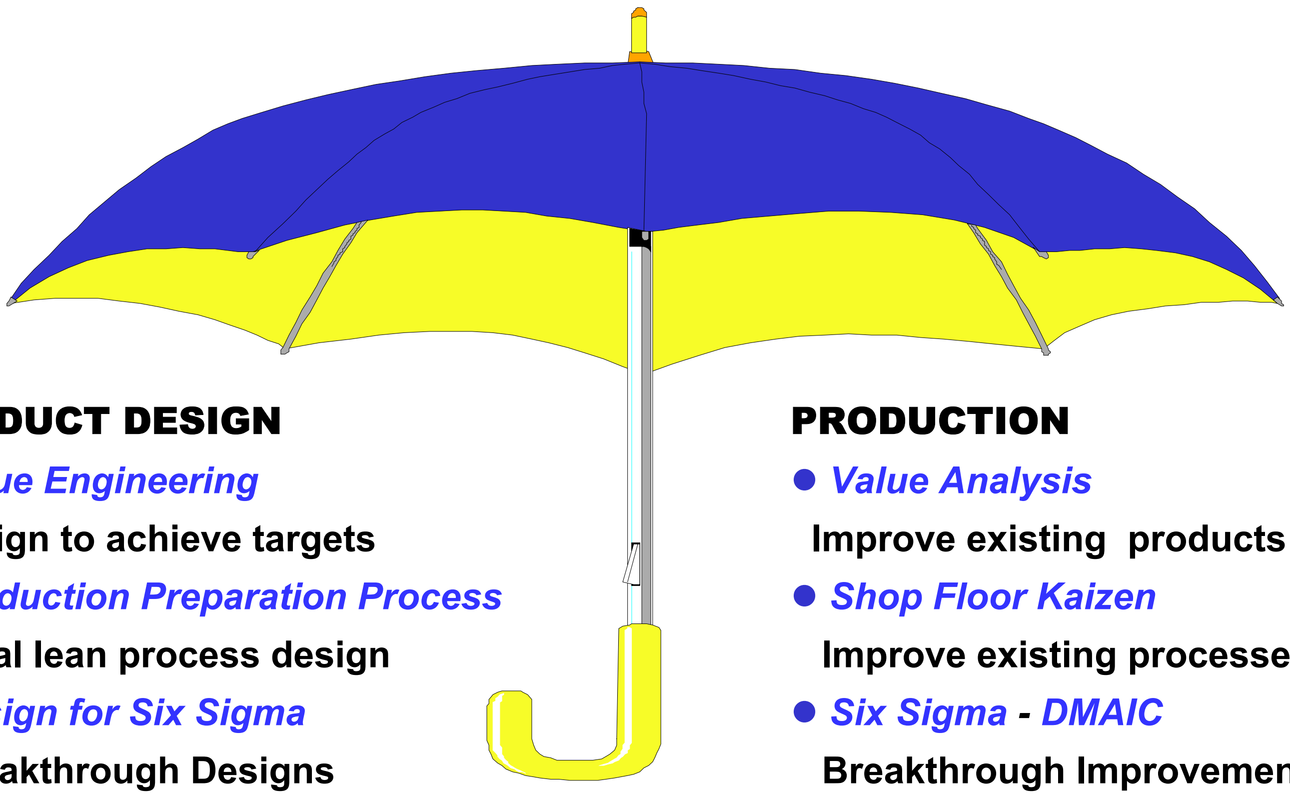
Freudenberg-NOK

Growtth Is An Acronym For **Get Rid Of Waste Through Team Harmony**, And Represents Freudenberg-NOK's Company-Wide Program Stressing Lean Business Practices.

Growtth® Six Sigma

Freudenberg NOK

Growtth® - Lean Systems



PRODUCT DESIGN

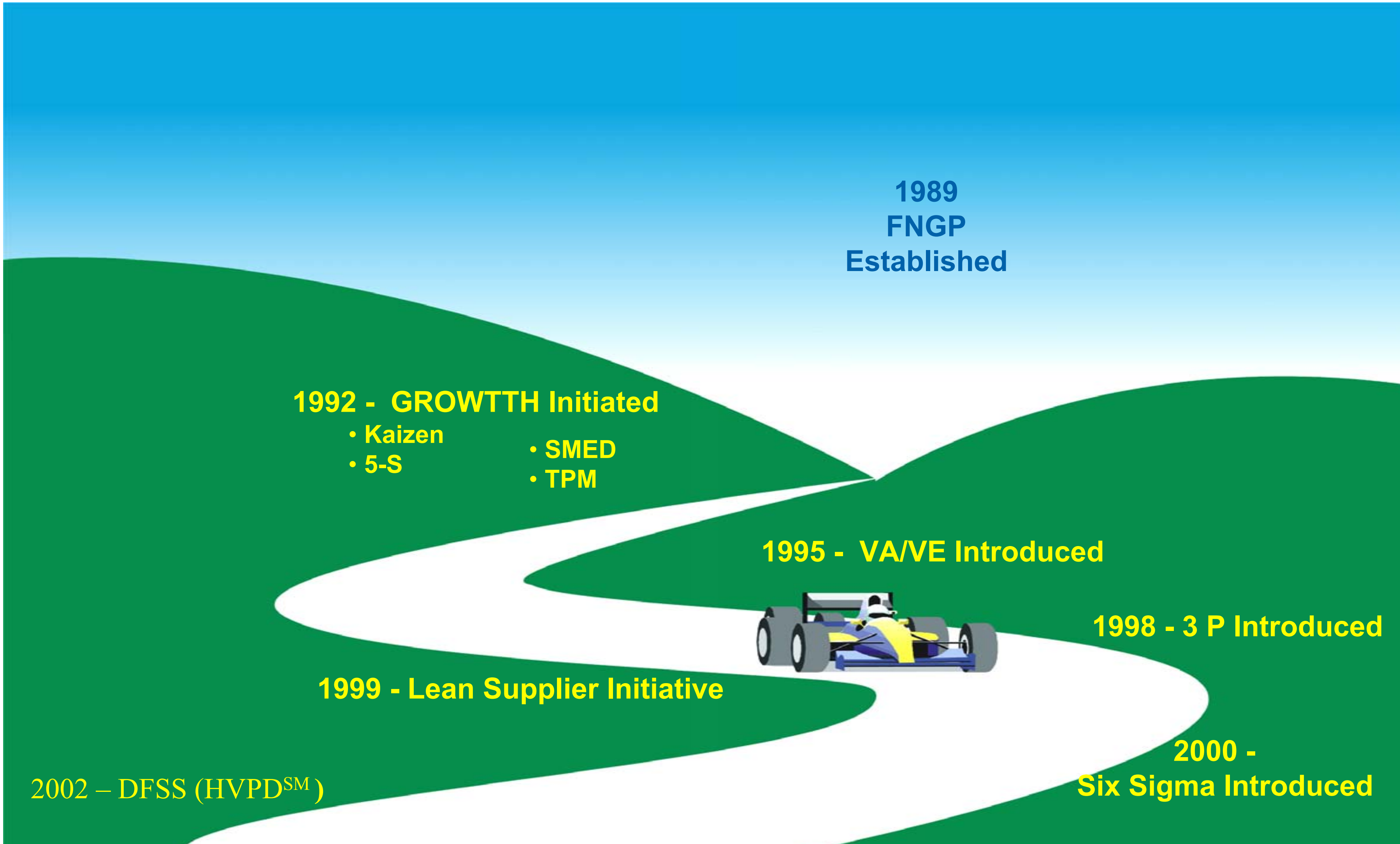
- ***Value Engineering***
  Design to achieve targets
- ***Production Preparation Process***
  Initial lean process design
- ***Design for Six Sigma***
  Breakthrough Designs

PRODUCTION

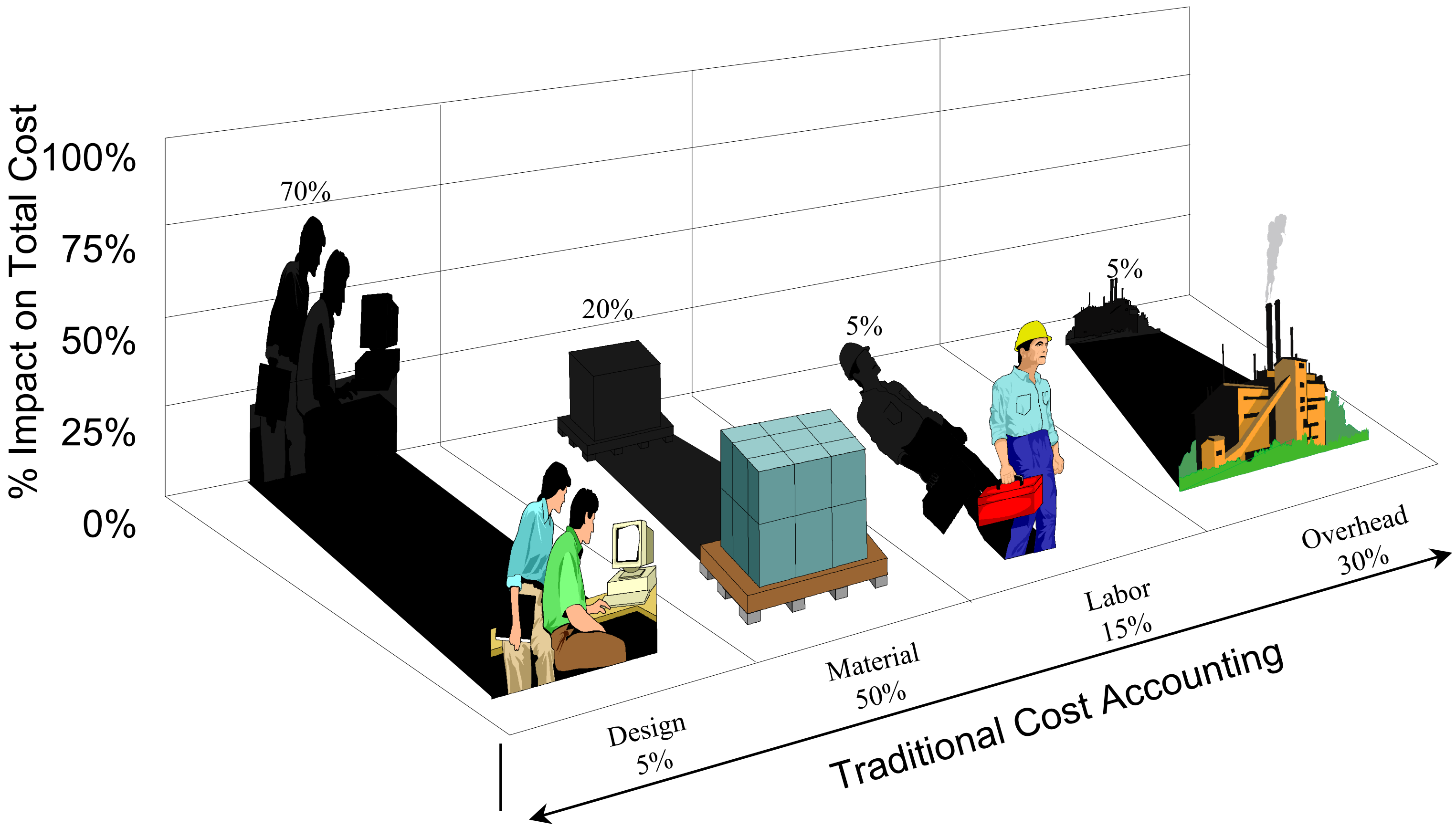
- ***Value Analysis***
  Improve existing products
- ***Shop Floor Kaizen***
  Improve existing processes
- ***Six Sigma* - *DMAIC***
  Breakthrough Improvements

Growtth Six Sigma

Freudenberg-NOK's Journey to Lean



Casting the Biggest Shadow



What is Design For Six Sigma

A design philosophy of systematic methodology, tools, and techniques which enable us to design products and processes that meet customer expectations and can be produced at the 6 sigma level.

DFSS incorporates the Value Methodology with the DMAIC methodology in a Lean Culture

DFSS Process

I
1. **Identify Customer requirements**: VE, QFD, CTQ
2. **Estimate Baseline:** Benchmark, Patent search, Product Scorecard, Process Map, Value Stream Map

D
3. **Determine Functional Requirements**: VE, DFMEA
4. **Generate, Evaluate, Select Design & Process Concept(s):** VE, 3P, TRIZ, Brainstorm

O
5. **Optimize Design and Process Concepts**: DOE, CAE, FEA, Simulation, Analytical models

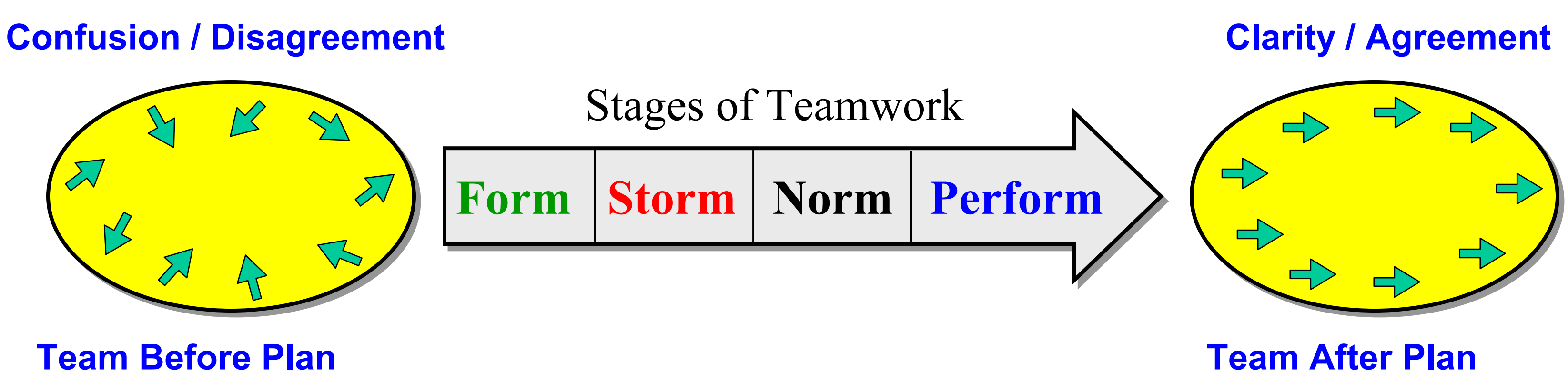
V
6. **Verify Design and Process**: PFMEA, DVP&R, PPAP
7. **Maintain the Gains**: Control Plan, SPC, Kaizen

Goal of DFSS is to create designs that are:

- Resource Efficient – LEAN
- Capable of very high yields regardless of volume
- Not affected by process variation; Robust
- Lead to a "flawless launch"
  - **Meets Performance Targets (Quality)**
  - **Meets Delivery Targets (On Time)**
  - **Meets Financial Targets (Target Cost)**

1. Identify Customer Requirements

- Customer needs must be addressed in all designs (product & process).
- Needs must be translated into technical, measurable terms to track improvement / success.
- CT Matrix provides comparable results as QFD.



Customers Requirements Document

Objective: Document & Prioritize the Customer's Requirements

SAMPLE for Brake Hose Assembly

	Cust. "Wants"	Import. Rating (10-High,1-Low)	Metrics / "Functional Req's" (Objective, Proactive, Representative, Controllable, No	Targets / Goals	Current Situation	Conflict / Gap
1	Hose Performance	9	Burst pressure psi	5000	5000	OK
2	No Corrosion	7	pass 160 hr salt sprsy	160 hrs	160+	OK
3	No Constrictions	10	pressure drop - % defect.	0	0.01%	OK
4	No Leakage	10	leak decay 15" @ 20 psi	0	2.70%	2.70%
5	Fit Routing	9	length and orientation			OK
6	Identification	7	per federal specs			OK
7	On Schedule	8	meet takt time (%otd)	100%	99.10%	OK
8	Piece Price	9	Target $/part	$xx.xxx	$zz.zzz	15% over
9	Damage free	8	visual appearance	100%		OK
10	Ease of insatllation	6	cycle time at line	15 sec.	21 sec.	6 seconds
11	Serviceability	5	"book" time	.15 hrs	.15 hrs	OK
12						
13						
14						
15						

Critical to Matrix

		Rating of Importance to Customer	9	7	10	10	9	7	8	7	8	5	6	8	9			
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
		Process Steps / Input Variables	HOSE Perfromance	No Corrosion	No Constrictions	No Leakage	Fit Routing - Orientation	Identification	Delivery on Schedule	Price / Cost	Damage Free	Serviceability	Installation by customer	Durability	Warranty	Attachment		Total
1	Hose Construction		10			3		9	5	9	2			9	9			455
2	Hose Dimensions		2		6	2	5		5	2	2			2	2			247
3	End Fittings																	0
4	Material			10	3				7	7	2			3	3			272
5	Dimensions				3	4	5		3	4		6	6					233
6	Brackets																	0
7	Material			10					7	5	2	1		3	3			233
8	Dimensions				5		7		3	3		1	1	2	3			212
9	Clips																	0
10	Material			10					5	5		2						155
11	Dimensions						1		2	2	2	3	3					88
12	Wrap Bracket Assy			10	6		7		5	3	3							278
13	1st. Crimp			7	6	8	7		5	3	2							329
14	2nd. Crimp			7	6	8	7	9	5	3	2							392
15	Pressure Test					1			5	5	5							125
16	Bracket Assy.			2			7		5	2	3							155
17	Shape Guage								1	2								22
18	Packaging			1				9	5	3	1							139
19	Receiving / Inspection							3	1	1	1							44
20																		0
																		0
Total			108	399	350	260	414	210	552	413	216	65	60	152	180	0	0	

This table provides the initial input to the FMEA. When each of the Output Variables (Requirements) are not correct, that represents potential "EFFECTS". When each Input Variable is not correct, that represents "CAUSES".

1. List the Key Process Output Variables (Requirements)
2. Rate each Output Variable on a 1-to-10 scale on the importantance to the customer
3. List Key Process Steps (Input Variables)
4. Rate each Process Step (Input Variable) relationship to each Output Variable on a 1-to-10 scale
5. Select the top Process Steps (Input Variables) to start the FMEA process; Determine how each selected Process Step (Input Variable) can "go wrong" and place that in the Failure Mode column of the FMEA.

2. Estimate Baseline

- Process Map
- Opportunity Count Worksheet
- Product Scorecard
- DFSS Worksheet
- Value Stream Map

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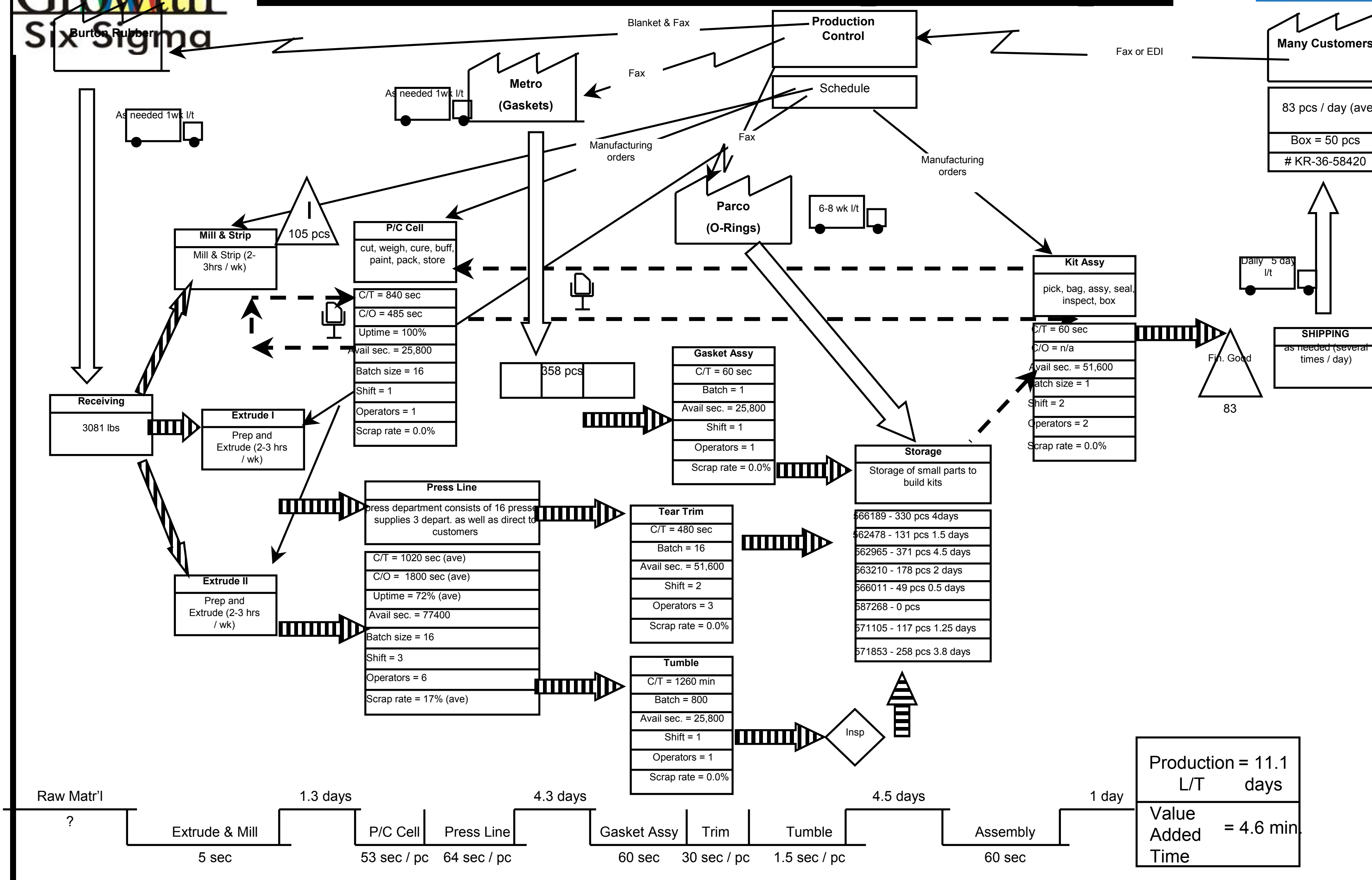
Product Scorecard

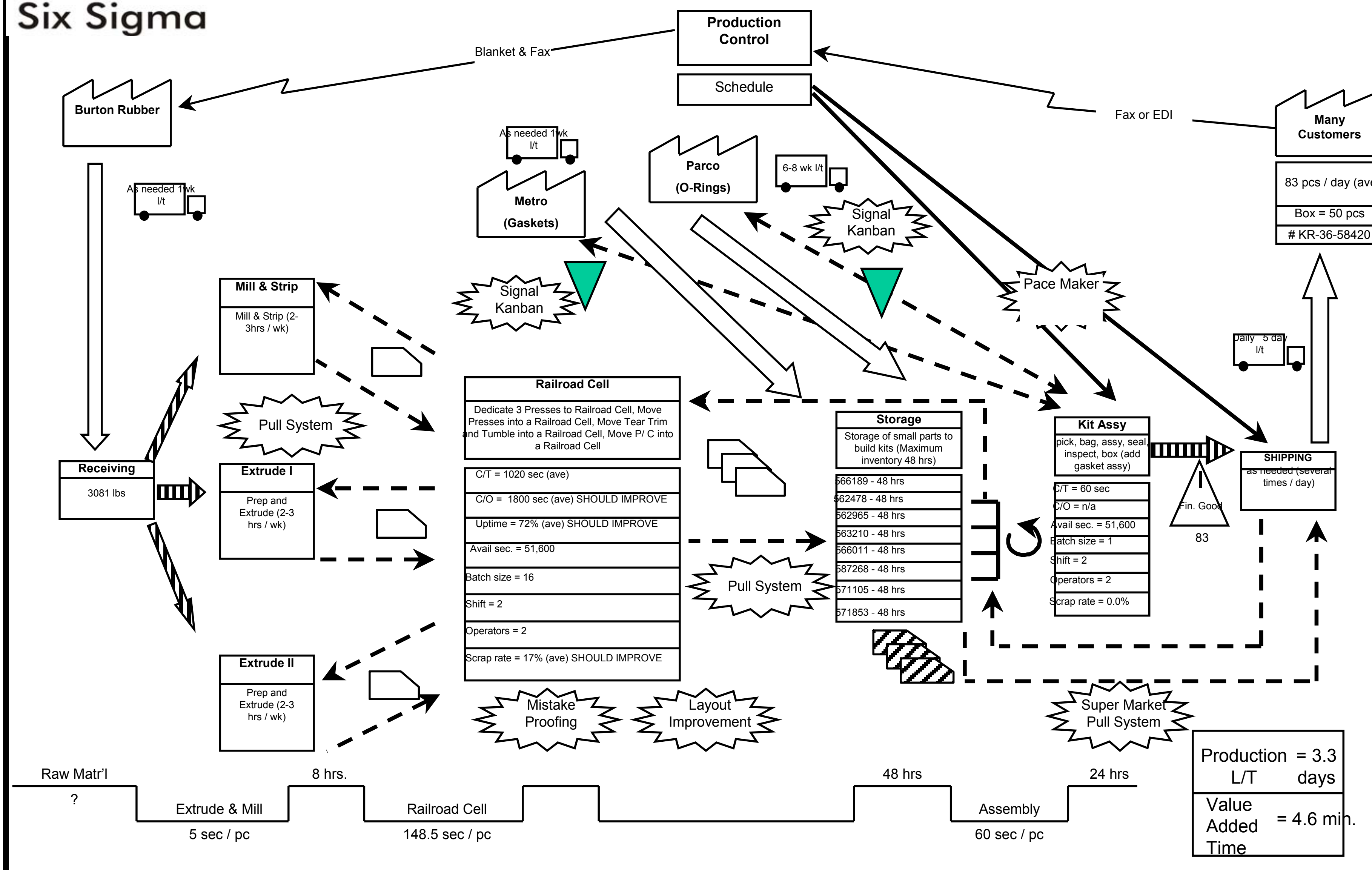
Product Name: Brake Hose Assy

Activity	Part σ DPU Est	Part σ Oppt. Count	Process σ DPU Est	Process σ Oppt. Count	Performance σ DPU Est	Performance σ Oppt. Count	Product σ DPU Est	Product σ Oppt. Count
Hose	0.000122	1						
1st. Crimp - Banjo	0.016970	1	0.062131	3				
2nd. Crimp - Female	0.016970	1	0.065611	4				
Cust Rejects					0.000010	1		
Internal Scrap					0.001021	1		
Leak Test Rejects			0.027246	0				
Totals	0.034062	3	0.154988	7	0.001031	2	0.190081	12
First Time Sigma	1.83		1.06		3.08		0.94	
DPU/Oppt.	0.011354		0.022141		0.000516		0.015840	
Yield/Oppt.	98.87%		97.81%		99.95%		98.43%	
Sigma/Oppt. LT	2.28		2.02		3.28		2.15	
Sigma/Oppt. ST	3.78		3.52		4.78		3.65	
First Time RTY	**96.65%**		**85.64%**		**99.90%**		**82.69%**	

VSM Current State Map (Example)



VSM Future State Map (Example)



3. Determine Functional Requirements

- Value Engineering – Function Analysis
- Design FMEA

This is the root cause determination step of the problem or opportunity….

(High Value 6-Sigma Design)

VA/VE JOB PLAN

Information Phase	- Select Project and Team, Define Scope and - Objectives, Perform Information Gathering Tasks
Function Phase	- Define Functions, Assign Costs to Functions - Identify Improvement Opportunities
Creative Phase	- Brainstorm ideas to Perform Function - “How Else Can We...” Functional Thinking
Evaluation Phase	- Idea Categorization, Idea Prioritization, ‘T’ Chart
Development Phase	- Value Ratio: V=F/C, Proposal Selection - Write Proposals and Action Plans
Implementation Phase	- Recommendation and Presentation - Implement Action Plan

Value Creation Sept 2003

Function Analysis

1

FNGP VA/VE COST/FUNCTION WORKSHEET

WORKSHOP PROJECT: 4406

PART or OPERATION	QTY.	DIRECT COST	FUNCTION - Active Verb / Measurable Noun							
Seal										
R/M Prep	1.0	0.190								
Case	1.0	0.060								
Case Treat	1.0	0.010								
Spring	1.0	0.020								
Grease	1.0	0.001								
Packaging	0.1	0.015								
Mold Cell	1.0	0.260								
Exten. Housing										
Casting Al	1.0	8.460								
Machining	1.0	1.050								
Bushing	1.0	0.640								
Ship Cover	1.0	0.110								
Doughnut	1.0	0.165								
Lube - ATF	1.0	1.090								
Extn. Hsg. - S/Asy.	1.0	3.390								
TOTALS		15.461	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Direct Costs EXCLUDE all Fixed burden & Overhead, S,G,&A, Margin

FUNCTION - PERCENTAGE:		1.000	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Cost Cards
BOM
Router

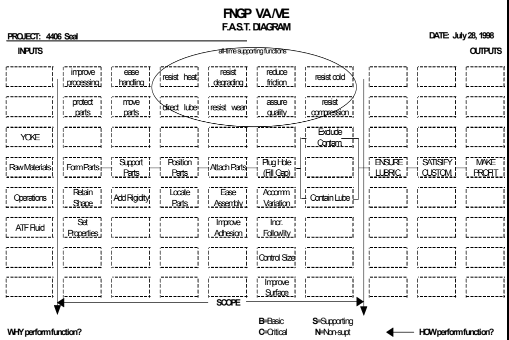
2

FUNCTION WORKSHEET

Part/Module Name: Rear Output Seal — Part No. UHO911-EO

Component/ Opr. No. From Cost Card	Part/Opr. Description "What it is"	Function Description "What it does" Verb - Noun	Class B,C S, NS	Remarks/Specs. How much?
UUHO911T	Rubber Prep. (T-599)	Fill Gap	C	Volume
		Accommodate Variation	S	Elastomer
		Resist Heat	S	250 - 275 F
		Resist Degradation	S	
		Resist Cold	S	
		Reduce Friction	S	
		Resist Wear	S	Wear Package
		Resist Compression	S	
		Improve Processing	N	Cure Package Mold Flow Engineered Waste

3



4

FNGP VA/VE COST/FUNCTION WORKSHEET

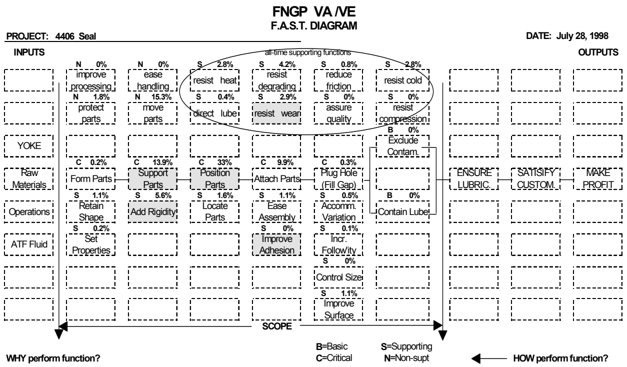
WORKSHOP PROJECT: 4406

PART or OPERATION	QTY.	DIRECT COST	FUNCTION - Active Verb / Measurable Noun: Plug Hole	Attach Parts	Posit. Parts	Supt. Parts	Form Parts	Accom. Var.	Iner. Follow	Impv. Surf.	Ease Assy.	Impr. Adh.	Locate Parts	Add Rigid
Seal														
R/M Prep		0.190	0.019					0.029						
Case		0.060				0.040								0.020
Case Treat		0.010		0.007								0.003		
Spring		0.020							0.020					
Grease		0.001												
Packaging		0.015												
Mold Cell		0.260			0.026		0.032							
Exten. Housing														
Casting Al		8.460			5.080	2.110								0.850
Machining		1.050		0.504						0.168	0.168		0.210	
Bushing		0.640												
Ship Cover		0.110												
Doughnut		0.165	0.033					0.050					0.041	
Lube - ATF		1.090												
Extn. Hsg. - S/Asy.		3.390		1.020										
TOTALS		15.461	0.052	1.531	5.106	2.150	0.032	0.079	0.020	0.168	0.168	0.003	0.251	0.870

Direct Costs EXCLUDE all Fixed burden & Overhead, S,G,&A, Margin

FUNCTION - PERCENTAGE:		1.000	0.3%	9.9%	33.0%	13.9%	0.2%	0.5%	0.1%	1.1%	1.1%	0.0%	1.6%	5.6%

5



Opportunities
Identified
Value mis-matches

4. Generate and Select Concepts

- Value Engineering – VE
- Production Preparation Process Kaizen – 3P
- Design for Manufacturing / Assembly – DFM/A
- Triz
- Brainstorming
- Or a set a such Techniques

VE & 3P in DFSS

Production Preparation (3P), which focuses on the production process, should be performed **concurrently** with Value Engineering (VE), which focuses on product design.

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Value Analysis / Value Engineering

VA/VE is a proven team oriented, creative, systematic, cross-functional approach that enhances decision making, improves products and processes, and increases customer satisfaction.

The objective of VA/VE is to improve value, as defined by: **Value = Function ÷ Cost**

where function is performance or quality and cost is the overall cost to deliver the functions. This goal complements that of Growtth by continually striving to eliminate waste or unwanted functions and cost in product design.

Growtth Six Sigma

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3P Objective

<u>P</u>roduction <u>P</u>reparation <u>P</u>rocess (3P) is a component of the Advanced Product Quality Planning (APQP) Process

The major focus of 3P is to ***minimize resources required to meet takt time.*** *

- Resources include: Capital, tooling, direct and indirect labor, floor space, WIP, etc.
- Takt Time is the rate at which the customer buys the product

Why Production Preparation?

1. Assure that quality is built into the design and the production processes.
2. Design products for ease of manufacturing using JIT principles - one piece flow, takt time and pull system.
3. Design manufacturing processes with built-in error proofing devices.
4. The mission of production preparation is to guarantee process capability to meet takt time with minimum resources such as capital, tooling, labor, floor space, WIP, etc.

But Above All

BUILD QUALITY INTO THE SYSTEM.

5. Optimize Concepts

- Robust Design or Parameter Design
  - Measure Energy Transformation
  - Optimize Function for Energy Transformation
- Other 6-Sigma Tools (Improve Phase):
  - DOE, Hypothesis Testing, Regression Analysis,

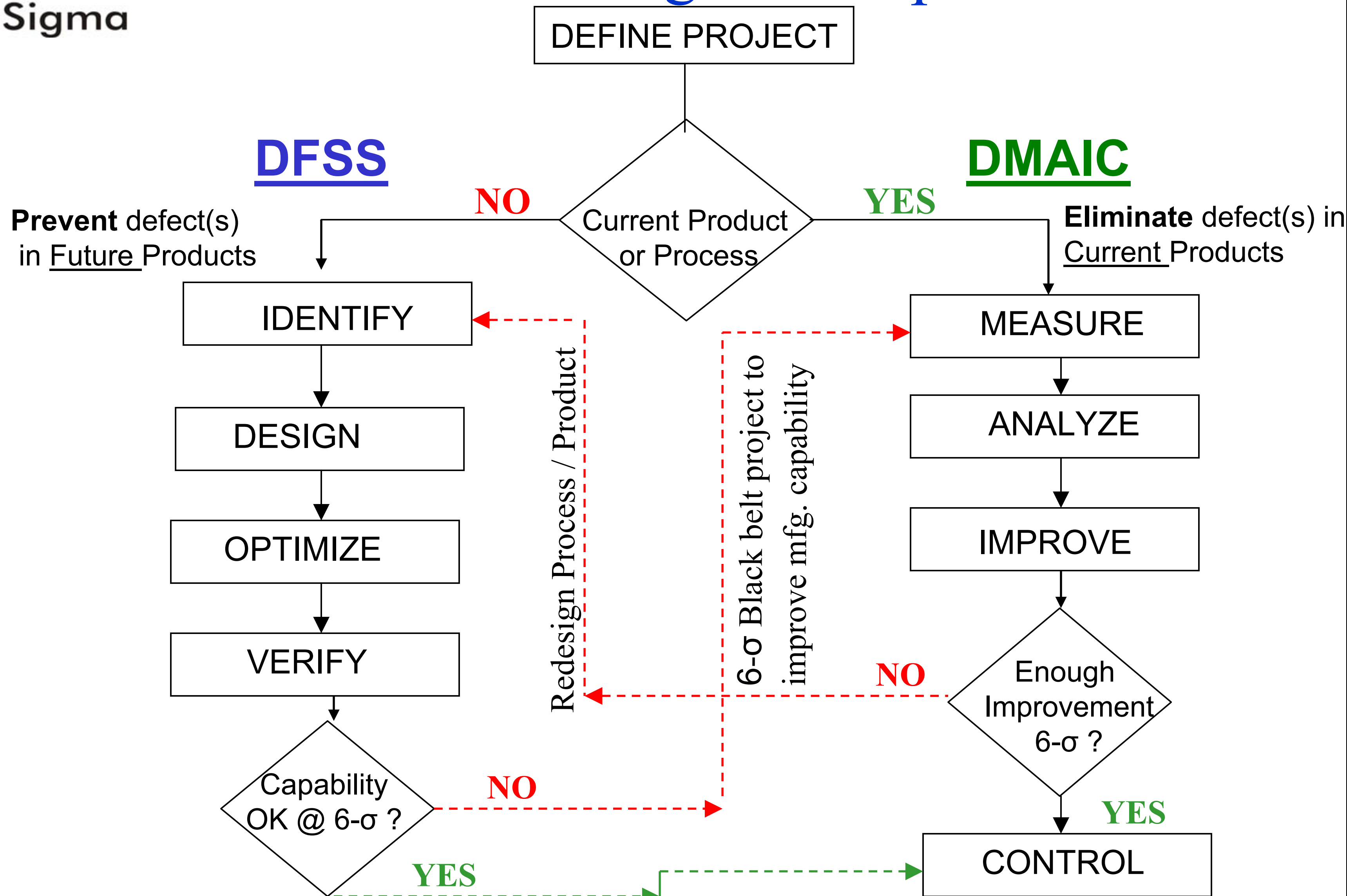
6. Verify Design and Process

- Design Verification – DV
- Process Verification – PV
- DVP&R
- PPAP

7. Final Steps

- Estimate Benefits –$$ Savings or Avoidance
- Bookshelf Solutions & Potential Solutions
- Complete Control Phase
  – PFMEA, Control Plan, SPC, etc.
- Next Project

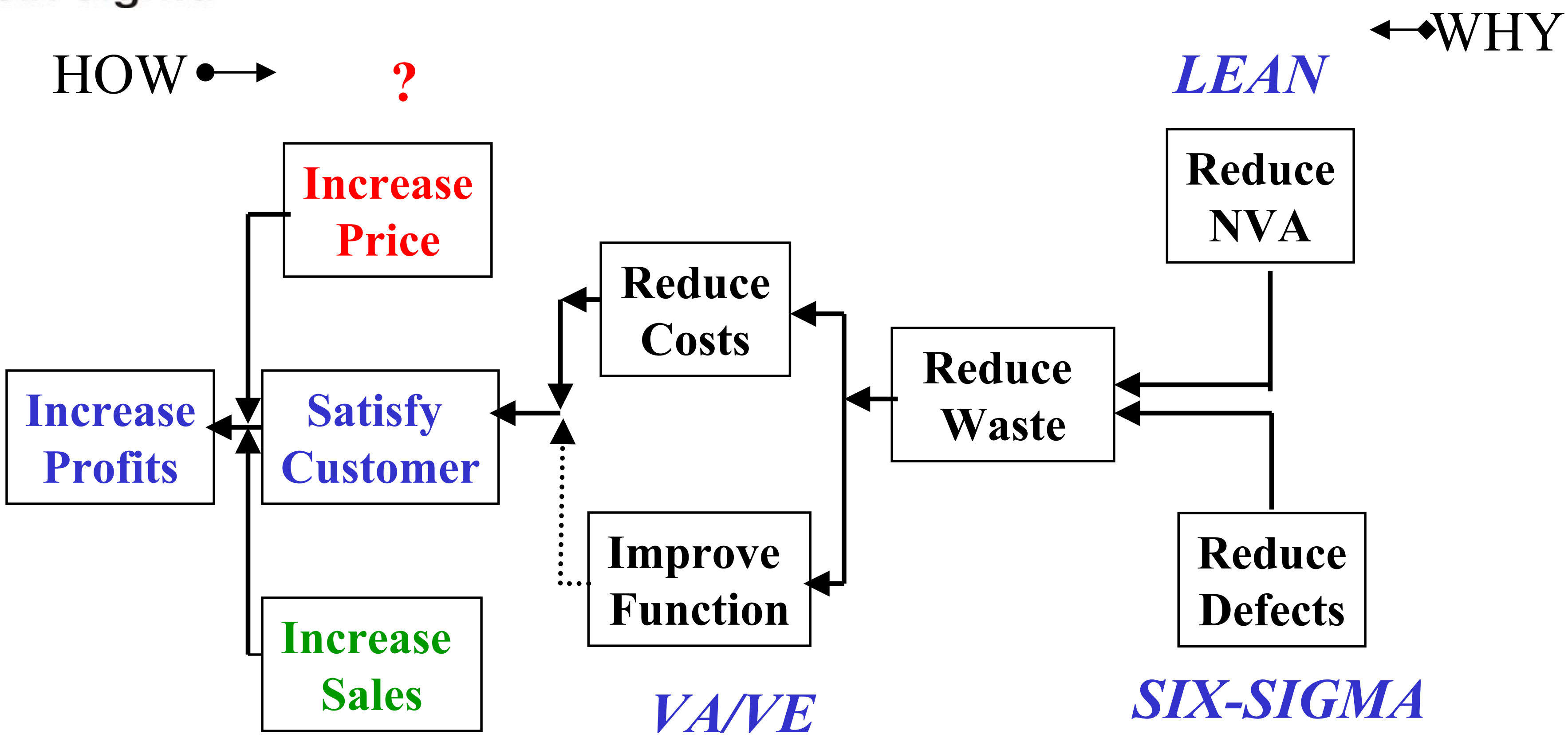
The Overall Six Sigma Perspective



6-Sigma vs. VM

	6-Sigma	VM
Where developed	Motorola	Gen. Electric
Methodology	Breakthrough Strategy - DMAIC	Job Plan 6-Phase
Deliverable	Defect Redn. DPMO	Value Impvt. V=F/C
Unique Feature	DMAIC	Function Analysis
Visibility (Champion)	Jack Welch - GE	Who ?
“Sold to”	CEOs & CFOs	Engineers & Managers

How Growtth Increases Profits



NB: This is NOT a FAST diagram

GROWTTH Tools & Techniques

VA / VE

DFSS

CFT

QFD

FMEAs

DFM/A

DOE

PPAP

Kaizen

3 P

APQP

TPM

Benchmarking

6 Sigma
DMAIC

Project Management

Using these tools give FNGP a competitive advantage by helping us learn what the customer needs and giving us the means to deliver a high value product.